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Environmentally Sustainable Household Consumption

From Aggregate Environmental Pressures to Indicators for Priority Fields of Action

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Abstract

During the UNCED conference in Rio de Janeiro 1992 unsustainable consumption and production patterns were identified as one of the key driving forces behind the unsustainable development of the world (Agenda 21, chapter 4). These consumption and production patterns are based on the European model of industrialisation, spread around the globe in the age of colonisation and brought to extremes by the upper-class of industrialised societies, in particular in the United States, but also in a number of countries in the South. Therefore, all states of the world share the task of developing sustainable consumption and production patterns, while particular responsibility rests with the industrialised nations of Europe, North America and Japan. They, and the thriving but small rich elite in the transition countries and in the South, form a global consumer society, with shared products, lifestyles and aspirations.

As it is essential to support the transition towards sustainable development by providing the proper information in an operational manner, the UNCED conference has called for the development of suitable means of information, and in particular for the development of sustainability indicators applicable throughout the world (Agenda 21, chapter 40). The UNDESA set of indicators for changing consumption and production patterns offers helpful advice in this regard but still lacks the theoretical underpinning needed to consistently complete it by defining the few still missing indicators.

This paper undertakes to suggest such a methodology based on the environmental space concept. It derives a set of science based indicators from this approach which are easily applicable in everyday life and analyses the environmental relevance of the consumption clusters chosen for analysis as well as the relevance of the phenomena characterised by the indicators suggested. As households are just one actor in the field of consumption, a qualitative assessment of influences is performed and the result depicting the key actors for each environmentally relevant consumption cluster is presented as an actor matrix.

Finally, the indicators derived are compared to those suggested by UNDESA, finding striking similarities. Based on this convergence in approaches the paper explains how the methodology developed could be used to develop the missing indicators UNDESA has been calling for.

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1. Introduction

Redirecting our societies and economies towards sustainability is a task that cannot be attributed to any subgroup of society – politicians, business leaders, NGOs, etc. – but one that needs to involve society at large if it is to be mastered effectively. The involvement of all "major groups" of society is one of the main institutional innovations the sustainability discourse has brought about (for details on institutional sustainability see Spangenberg et al. 2000). Households through their demand-side influence on the economy are potentially one of these major actors, but as long as they do not act in a coherent manner, they will remain a "sleeping giant". This is why reliable and easily understandable information is of crucial importance if the already given environmental awareness of households is to become a relevant driving force in the market.

Chapter 4 of Agenda 21 underlines the need to change consumption and production patterns, by stating that *"the major cause of the continued degradation of the global environment is the unsustainable pattern of consumption and production, particularly in industrialised countries.…Changing consumption patterns will require a multi pronged strategy focusing on demand, meeting the basic needs for the poor, and reducing wastage and the use of finite resources in the production process."* (United Nations 1992).

Any such change in consumption patterns needs to attribute an important role to consumer behaviour. Whereas economic incentives through green taxes are discussed as a means to modify consumption patterns based on the prevailing economic preferences by raising the price of environmentally suspicious products, new means of communication are sought for two reasons. On the one hand, they should enhance public support for the introduction of the economic incentives, and on the other hand they should stimulate the further evolution of household consumption patterns to give greater emphasis to the environmental impacts of the goods and services consumed. Whether the reference to an environmental cause is able to motivate 'green purchasing' depends on a number of factors, not least on the communication itself. In particular, the cause given "must strike a sensitive chord,…information must be disseminated in relation to this cause and…the cause must be related to some precise consumption elements" (Zaccai 2000).

Sustainability indicators have long been discussed as one means of communication for these purposes, as a means to bridge the gap between environmental causes and specific elements of consumption. In Agenda 21, chapter 40 calls for the development of indicators for sustainable development as concrete, issue-related guidance for taking and evaluating action. However, to be effective, these indicators have to be integrated into a broader communication strategy which emphasises the relation to the environmental causes, and the environmental (and other, e.g. health) benefits resulting from making use of the orientation provided by the indicators. Such an indicator-based communication strategy can also serve to overcome the “three traps” preventing actors from transforming their awareness into everyday action in eco-social dilemma situations (causing “the tragedy of the commons”), i.e. in situations when those to invest efforts are separated from the beneficiaries by means of time, space or social grouping (Reisch, Scherhorn 1999).

The issue of developing appropriate indicators for sustainable consumption has been high on the political agenda ever since the UNCED conference (see e.g. Miljoverndepartementet 1995, VROM 1994). However, neither the consumption indicators included in the set of 134 sustainability indicators proposed by the CSD (UNDPCSD 1996) and tested by a number of pilot countries, nor the revised set published in 2000 (UNDSD 2000) met a number of reservations.

One case in point is the issue of sustainable consumption and production patterns, which is an important part of Agenda 21 and in the course of the indicator testing had been identified as a common priority for developing as well as industrialised countries. Nonetheless, the UN Division for Sustainable Development UNDSD when summing up the testing results had to state that *“gaps were identified in the working list of indicators on complex issues such as…production and consumption patterns…”*. As the revised version builds upon the indicators tested, reducing their number rather than increasing it, the UNCSD’s hope for improvement was based on an additional process of indicator development initiated by the UN: *“It is to be noted that separate work is underway to improve and expand the list of indicators on consumption and production.”* (UNDSD 1999).

This “separate work” was made an official priority when the CSD at its 5th session 1997 called upon the Secretariat and governments to *“develop core indicators to monitor critical trends in consumption and production patterns, with industrialised countries taking the lead.”* (UNDSD 1998, p. 5). The International Work Programme on Changing Consumption and Production Patterns IWPCCPP, established by the CSD during its 3rd session 1995 developed a set of sustainable consumption indicators, through literature analysis, the circulation of drafts (UNDPCSD 1996), consultation rounds and a workshop in March 1998 (UNDSD 1998). The indicators and comments regarding their purposes were published in 1998 (UNDESA 1998).

However, for a few indicators related to household consumption, no methodologies have been developed so far. It was against this background that the

German government in 1999 decided to provide some recent results of research it had commissioned by organising a seminar as a side event to the CSD VII Intersessional Meeting, hoping that the results might contribute to solving the problem of developing indicators for sustainable household consumption.

This paper summarises the research results on indicators of environmentally sustainable household consumption, with a focus on the methodological framework, as this is applicable to the UNCSD indicator development process. Beyond the indicators already developed (Lorek, Spangenberg 2001), this framework can serve as a theoretical underpinning for consumption analysis (Spangenberg, Lorek 2001) and thus for the indicators developed by UNCSD as well as a basis for deriving the ones for which the methodology sheets still need to be developed.

In chapter 2 of this paper, the indicators developed in the framework of the International Work Programme on Changing Consumption and Production Patterns are described by Catherine Rubbens, UNDESA, documented with the kind permission of the author from the above-mentioned workshop in February 1999. It illustrates in a very comprehensive manner the achievements of the IWPCCPP programme as well as the questions still open today. The environmental impact of household consumption can be decomposed into three determinants (Röpke 2001):

- the level of consumption,
- the composition of consumption, and
- the environmental intensity of goods and services produced for consumption, including both direct and indirect effects.

According to this decomposition, any analysis should be based on the environmental intensity of products, and it should capture the level and composition of consumption. Consequently, the research results presented in this paper both refer to the identification of those areas of consumption in which private households can make significant contributions to environmental sustainability (effects), and how to present these areas by means of a transparent and comprehensive set of indicators (reflecting composition and measuring levels).

The analysis of the environmental impacts of households is focused on consumption clusters that permit to depict different life spheres of the private household. Two criteria guided the investigation of the relevance of these clusters:

1. The significance of the consumption cluster: Does it justify high-priority action regarding environmental concerns?

2. The potential influence of households: Are households the key actor determining the environmental impacts originating from a consumption cluster?

Since most current sets of indicators for the environmental impacts of household consumption cover eclectically selected and widely differing aspects of the issue, first of all a conception sound basis had to be established (chapter 3). The proposal presented is based upon analysis of the linkage between resource consumption as a driving force and the state of current environmental problems. As a result, resource consumption is identified as a simplified, but reliable presentation of trends in environmental burden generation. In other words, growing resource consumption goes together with growing environmental pressures and vice versa, although not necessarily proportionally. The key resources and relevant consumption clusters identified are (Lorek et al. 1999, Röpke 2001):

- energy and material consumption, as well as land use, are the basic resources, and
- construction and housing, food/nutrition and transport (in this order) are consumption clusters which call for high-priority action for reducing environmental use.

This conception base for indicator selection can be applied to all industrialised countries. It is possible, however, to adapt the system of indicators to the diversity of country size, infrastructure, climate, heating, etc., by “tailor-made” indicators. They could be developed along the same line of thought (consumption statistic derived prioritising) used in the study presented here. Some further modification of the selection criteria for consumption cluster indicators might be needed for (other, notably) developing countries due to global differences in wealth, preferences, consumption patterns, culture, etc.

From this starting point, indicators for environmentally sustainable household consumption have been derived which are presented in chapter 4.

Chapter 5 compares the results to those of the IWPCCPP programme and offers some conclusions how the work presented here could contribute to the elaboration of the still missing consumption indicators.

2. Measuring Changes in Consumption and Production Patterns: The DSD/DESA Indicators for a Sustainable Consumption[1]

(by Catherine Rubbens, Dept. of Economic and Social Affairs,
Division for Sustainable Development)

2.1 Selection of a core set of indicators for changing consumption and production patterns

The initiative of the Division for Sustainable Development to select a core set of indicators for changing consumption and production patterns is based on two Work Programmes adopted by the Commission on Sustainable Development at its third session in 1995: the International Work Programme on Changing Consumption and Production Patterns IWPCCPP, and the Work Programme on Indicators of Sustainable Development WPISD (United Nations 1995).

The IWPCCPP contains five work elements: (i) the assessment of trends in consumption and production patterns, (ii) impacts on developing countries of changes in consumption patterns in developed countries, (iii) policy measures to address unsustainable consumption and production patterns, (iv) voluntary commitments from countries to achieve more sustainable consumption and production (including work on indicators), and (v) the extension of the United Nations Guidelines for Consumer Protection.

Highlights from the implementation of the WPISD have been the adoption by the Commission on Sustainable Development of 134 indicators of sustainable development covering all the aspects of Agenda 21, the identification of lead agencies responsible for drafting methodology sheets for each of these indicators, publication of these methodology sheets for use at the national level (UNDPCSD 1996), and the testing of the indicators by 22 testing countries (UNDSD 1999). A revision of the WPISD has taken place in 2001, in the context of the 9th session of the Commission (UNDSD 2000; United Nations 2001).

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1 This chapter is based on a presentation during the side event on sustainable consumption indicators at the CSD VII Intersessional, February 1999

While the indicators of sustainable development include some indicators for consumption and production patterns, it was generally recognised that further work was needed to develop additional indicators for this topic. The Division for Sustainable Development therefore initiated a consultative process at the international level with a wide variety of partners involved in the implementation of the IWPCCPP. A draft document with proposals for indicators was circulated among participants in this process (UNDPCSD 1996), and a workshop on the selection of core indicators for consumption and production patterns was hosted by the Division in New York on 2-3 March 1998 (UNDSD 1998). At this workshop, 17 core indicators for changing consumption and production patterns were selected. The workshop discussions and its outcome are reflected in the publication *Measuring Changes in Consumption and Production Patterns – A Set of Indicators* (UNDESA 1998).

2.2 Presentation of the core set

On the basis of the discussions among experts in the above consultative process, the Division for Sustainable Development proposed indicators in a structure subdivided into Key Resources and Consumption Clusters.

The workshop selected:

Eight indicators for the Key Resources:
- Energy;
- Materials;
- Water; and
- Land

Nine indicators for the Consumption Clusters:
- Mobility;
- Consumer goods and services;
- Buildings and housekeeping;
- Food; and
- Recreation

2.3 Status of Activities

In order to facilitate the development of methodology sheets for the 17 core set indicators, the Division for Sustainable Development has identified lead agencies to develop methodology sheets.

Lead agencies have committed to this task for the following nine indicators (name of the lead agency in brackets):

- Annual energy consumption per capita (UN Statistics Division)
- Share of renewable energy in total energy consumption (UN Statistics Division)
- Energy prices (Eurostat)
- Total material requirements (World Resources Institute)
- Intensity of material use (UNCTAD)
- Number of road vehicles (Eurostat)
- Residential energy and water use per household (Habitat)
- Average household size (Habitat)
- Intensity of energy use (International Energy Agency)

For some indicators, the identification of possible lead agencies needed some more consultations:

- Land use
- Distance travelled per capita by mode of transport
- Spending on recreation as share of disposable income
- Time spent on leisure, paid and unpaid work, and travelling

Some indicators – particularly those selected for the Consumption Clusters – are quite innovative, and currently not in use in any country. Further work is needed for the development of methodologies for these indicators before a lead agency can be identified. In December 1998, the Division for Sustainable Development sent out a request to a number of organisations to provide support in the development of these indicators. However, so far no final solution has been found.

The indicators that need more careful consideration before methodology sheets can be developed, are the following:

- Intensity of water use
- Retail sales of selected goods per capita
- Market share of more sustainably produced goods and services
- Market share of more sustainably produced food

More information and regular updates regarding this process can be found on the webpage: http://www.un.org/esa/sustdev/cpp1224.htm.

Table 2.1: Indicators

CCPP Key Resources	**Indicators**
Energy	Consumption per year per person Energy intensity Energy price Share of renewables
Materials	TMR
Water	Water intensity
Land	Land use
CCPP Consumption Clusters	**Indicators**
Mobility	Distance travelled No. of vehicles
Building and Housekeeping	Energy use Water use Persons per flat
Food	% more sustainably produced
Recreation	Spending (time & money) as % of disposable income
Consumer Goods and Services	Retail sales of selected goods per capita Market share of sustainably produced goods and services

3. Environmentally Sustainable Household Consumption: The Conceptual Basis

In particular in the industrialised countries there has been an ongoing dispute about the importance and influence of private households with respect to environmental resource consumption (see e.g. SustainAbility 1994; VROM 1994; Miljoverndepartementet 1995; Lass, Reusswig 1997). However, although "*the unsustainable pattern of consumption and production, particularly in industrialised countries*" had been identified to be a *"major cause of the continued degradation of the global environment"* (United Nations 1993), research on the areas in which households can make a significant contribution to sustainable consumption is still quite limited (see, for example, the Int. J. Sustainable Development special issue on sustainable consumption, No 1/2001).

In order to identify these areas, first the most appropriate kind of accounting system for an actor-centred approach ("where can they really make a difference?") to household consumption has to be identified. Any assessment of the environmental impact of household consumption if intended to guide consumers must permit to compare the goods and services consumed regarding their respective environmental impact. Doing this on the basis of their contribution to the most debated environmental problems like climate change, eutrophication, etc. necessitates the aggregation of environmental effects. This is a highly complex process (most advanced in EuroStat 1999), based on subjective assessments of relative relevance as much as on scientific measurements. For the average consumer, its components and in particular the weighing factors needed for the aggregation procedure are all but transparent. Consequently, the usefulness of any such methodology is limited as regards the everyday use in the shopping mall. Therefore a transparent and simple, but still directionally safe system of assessing the environmental impacts based on an evaluation of the current accounting methodologies has to be developed that can be used to identify the relevant aspects of consumer behaviour.

3.1 Frames for accounting

Household consumption is usually defined either based on macro-level economics (households as final users), or on the micro level by domestic science analysis (counting the equipment of a household and accounting for the in-house consumption of energy and water). The first frame focuses on private consumption as represented in the system of national accounts SNA, the second deals with individual consumer behaviour within the household. Consequently, in the first frame all upstream environmental impacts are allocated to the consumer/household, whereas the second one includes hardly any upstream analysis.

The methodology of national economic accounting is based on the premise that goods and services are produced to meet demands of final users: production is no end in itself. Accordingly, all production efforts, upstream from the final consumption and including the resources consumed as well as the pollution released, can be allocated to specific end-uses.

The end-use is categorised into private consumption, government consumption, fixed assets and exports. However, the government's demands for goods and services also serve the needs of the population, e.g. the demand for security or education. Consequently, since publicly produced services are consumed privately, government consumption could be considered an intermediate with private consumption the final end-use (services going to the business sector do serve private consumption indirectly). The case is similar for fixed assets: Since they are a necessary precondition for the production of consumer goods or intermediates, they as well could be attributed to the final purpose of private consumption. Only the exports cannot be ascribed to the inland population.

As a result, in any national economy 80 percent or more of the domestic environmental resource consumption can be allocated to private consumption and its actors, the households, and with a trade deficit the figure rises above 100 percent. This approach serves the purpose of monitoring the entire life cycle of the consumption of goods and services from cradle to grave, but gives no hints as to which actors might be in a position to influence the environmentally relevant resource consumption. In this sense, private consumption as defined in the SNA and/or extended according to the argumentation above is a "sink category", not an actor's category and will allocate a much higher share of environmental impacts to the households than they will be able to actively influence in reality.

The situation is the opposite for the second frame, the domestic science approach. Since accounting for the goods consumed in the households, it is the standard basis for the educational and consultancy efforts of environment and consumer organisations. The main items accounted for include domestic electricity and water consumption, the frequency of electrical appliances ownership and purchases of products with environmental labels, however without being able to quantify the upstream environmental impacts. The information is used to develop green consumer guides, shopping lists and household consumption statistics (see e.g. SustainAbility 1994; UBA 1994), again without being able to base this advice on a life-cycle-wide, full-scale environmental assessment.

A further problem arises from the frequent mixture of these two approaches, without explicitly clarifying which one has been used to establish which aspect of the environmental relevance of household consumption. As a result, for example, the average per capita energy consumption is reported alongside the households' equipment level with a microwave or other applications (OECD 1998). The environmental relevance of such reporting remains unclear or at best non-quantifiable. To illustrate the lack of a coherent, policy relevant structure as well as the data abundance, the OECD indicators for key household consumption trends are documented in the box.

Box: OECD indicators for key household consumption trends

Transport and Communication

Road traffic and vehicle intensities:
- Total passenger-km and intensities in passenger-km per capita
- By mode (rail, road, air) in passenger-km, as % of total
- Road traffic by passenger cars in vehicle-km
- By type (share of public transport, in % of total mode)
- Passenger car stocks, structure: % equipped with catalytic converters, % of cars older than 10 years, ownership (number of passenger cars per capita)

Air emissions from road transport: Energy consumption by transport:
- Consumption of road fuels: total in litres per capita or litres per vehicle-km driven by passenger cars; by type of fuel (diesel, leaded gasoline, unleaded gasoline) as % of total
- Total trends and intensities, and by mode (road, rail, air) in toe (ton oil equivalent)and as % of total road fuel prices and taxes

Communication tools:
- Circulation of daily and non-daily newspapers and periodicals (number and circulation by 1000 inhabitants)
- Telephone lines, computers and/or internet connections per 100 inhabitants

Consumption of Durable and Non-durable Goods

Household consumption expenditure by type of good:
- Ownership of selected commodities per household or per capita (e.g. radio, TV, video, refrigerator, washing machine, dryer, microwave);
- Average length of product life, selected by product groups (to be specified)

Food consumption intensities and patterns:
- by type of food (fish, meat, etc.) in kg per capita, as % of total
- by growing method and level of process (share of processed food, share of organically grown produce over total agricultural produce consumed) as % of total

Paper consumption and recycling:
- Paper consumption intensities (per capita, per unit of GDP) and related elasticities (% change in consumption/% change in GDP over the same period)

Household waste generation and management

Recreation and Tourism

- (% of population living within 15 min of a green area)

International tourist receipts in real terms

Household consumption expenditure on recreation

Leisure travel as % of total passenger-km

Housing Related Energy and Water Consumption

Total final energy consumption:
- intensity and structure by type of final use (as % of total),
- share of consumption of renewable energy resources (as % of total)

Air emissions from residential energy use:
- intensity (toe [ton oil equivalent] per household or capita),
- structure by type of energy, electricity, natural gas, other (as % of total)

Total water abstraction:
- consumption intensities (litres per capita per day)
- consumption structure by type of use (bathing and showering, washing machine, dish washing, toilet flushing, drinking and cooking, external use, miscellaneous)

Energy prices and taxes

Public water supply and price

Waste water treatment

Aside from these household-specific indicators targeted at environmental concerns, the OECD has suggested some “Economic” and “Socio-Demographic Indicators”:

Economic Trends

Consumption expenditure shares of GDP:
- Expenditure shares of GDP in US$ per capita, and as a % of GDP (include consumer expenditure, investments and net trade, stock building and balancing items). Standard SNA definitions are applied

Net savings per capita, savings rates:
- Trends in annual public and private saving by country, measured as % of GDP
- Genuine savings, i.e. “the true rate of saving of a nation after accounting for the depreciation of produced assets, the depletion of natural resources, investments in human capital, and the global damages from carbon emission”

Government/public final consumption expenditure:
- level and trends in US$ per capita and as % of GDP
- structural changes, by purpose as % of total

Household/private final consumption expenditure (PFCE):
- level and trends in US$ per capita and as % of GDP
- structural changes, by purpose, by type of good, as % of total PFCE

Consumer price index

Socio-demographic Trends

- Household size

Population Structure and density:
- Urban versus rural population: in 1000 inhabitants, and as % of total population
- Dependency ratio (population <15 and >65 as % of the potential labour force ages 15-65) in urban and rural areas
- Ageing index (Population >64/population <15)

Source: OECD 1998, Indicator list and methodology sheets

While the macro reporting approach does not deliver advice to the consumer supporting her or his day-to-day decision making, the approach of accounting for the in-house consumption cannot bridge the gap between counter and kitchen on the one and the environment on the other hand. In reality however, households can do so, at least to a certain degree.

Obviously, the real influence of consumers is somewhere between what is covered by the two different measures described, making a new, actor-centred approach necessary. At first glance it seems plausible to define a third level in between the two established ones, reflecting the real influence of consumers. This however turns out to unworkable, since demand-side influence is a moving target. How much influence consumers have is dependent on a number of factors and differing not only between sectors and products/services (e.g. by closeness to the end-user or substitutability) and consumption clusters (e.g. through different elasticities), but also between social groups according to their lifestyles, levels of commitment, information and purchasing power. Each of these factors (and many more) is influencing the day-to-day behaviour in private households.

As it is obviously not possible to define a general accounting framework, the assessment of consumer influence has to be differentiated according to different consumption clusters. For the purpose of developing generally applicable sets of indicators, however, sociological characteristics cannot be taken into account since they differ too much between regions and societies. Nonetheless on the national level they provide important *additional information*, which in particular could be used to derive group specific guidance to greening household consumption (see e.g. Scherhorn 1991, 1993; Schultz, Empacher, Schramm 1999).

On the macro level, however, the task is to identify the most environmentally relevant consumption clusters and specify the environmental impact of household consumption accordingly. A precondition for this step, however, is to derive a simplified, but directionally safe measure of environmental disturbance.

3.2 Environmental Disturbance and Resource Consumption

"Based on the idea of a limited system, it makes sense to say that the human economy has a 'size' in relation to the natural system, of which it is a part" (Röpke 2001). Ultimately, most environmental problems are related to the growth of this 'size', and the following section of this paper is dedicated to demonstrating this fact.

Any meaningful assessment of human-made environmental distortions, diverse as they are in their nature as well as in their causes and origins, must be based on a life-cycle-wide approach, from resource mining to final disposal. The steps to be taken into account along the chain of production (Schmidt-Bleek 1994, 1999) include consumption and disposal:

- environmental impacts caused by the extraction of resources and the translocation of masses, which, even when the latter possess no commercial value like drainage water or overburden, significantly affect the environmental balance, albeit often in an unspecified way (Spangenberg et al. 1999).
- the use of substances which are deliberately dissipated in the environment for a specific purpose, e.g. pesticides or fertilisers in agriculture or salt on icy roads in winter time,

as well as
- emissions and deposition of solid, fluid and gaseous wastes, released into the environment as a result or side-effects of human activities like CO_2 from the energy consumption during manufacturing and use of a product.

These human-caused impacts have also been described as source (input), use (hazards) and sink (output) functions (Metzner 1998) of the consumption process, seen from the outside, i.e. the environment (and in brackets from inside).

3.2.1 The Input Based Approach

Usually environmental stresses are characterised by the symptoms they cause like climate change or acidification of freshwater, or by the pressures causing these symptoms like greenhouse gas emissions and cation immissions. However, since the list of pressing environmental problems is a long one, and since different substances can act in a synergistic way affecting several symptoms (like CFCs causing climate change as well as ozone depletion), simplification is needed and usually achieved by aggregation. This is a scientifically sound procedure as long as the aggregation is based on comparable physico-chemical effects of the respective substances, resulting in indexes based on a common unit of measurement like the Ozone Depletion Potential ODP or the Greenhouse Warming Potential GWP (on the methodology see Statistisches Bundesamt 1997). This level of aggregation, however, still leaves us with a high variety of indicators to be taken into account, and any further step of aggregation is based on subjective value judgements (Spangenberg, Bonniot 1998; EuroStat 1999), like, for example, the aggregation of ODP and GWP into a single measureless "atmospheric quality index". Obviously, in this case bottom-up aggregation has reached the limits of meaningful application and must be complemented, e.g. by a top-down analysis of disturbance factors as a suitable methodology to provide a simplified and more general view.

Furthermore, the end-of-the-pipe environmental protection of the 70s and 80s, putting the emphasis on measuring and regulating the intentional output (product quality) as well as the unintentional one (effluents) by command-and-control policies is reaching its economic and administrative limits. At the turn of the new millennium, new approaches are needed, from the level of instruments (contracts and voluntary agreements – agree-and-control – complementing legislation) to the basic approach to measurement and regulation itself. With increasing attention given not only to the quality of outputs, but to the absolute quantity of throughputs, the scale of the economy (Daly 1996) becomes an increasingly important topic, and accordingly more attention is paid to the input side (Schmidt-Bleek 1992).

Every human activity needs material as its physical basis, energy to go ahead and a realm where it takes place, i.e. area. Material flows, energy consumption and land use are thus the primary factors of environment use and thus disturbance potentials on the input side, whereas emissions, toxins and other effluents are the (traditionally more prominent) pressures on the output side of the industrial metabolism (Ayres, Simonis 1994). So, for example, the Presidency Discussion Paper for the Finnish EU presidency 1999 stated: *"It seems clear that environmental policy can no longer be targeted only at remedying problems already caused by various economic activities. New approaches will have to found to attack the very roots of environmental problems and a new strategy be developed that would lead towards sustainable patterns of production and consumption. This means, inter alia, that eco-efficiency must be improved and production methods become less energy intensive and less wasteful of raw materials."* (Finnish Environment Ministry 1999). Consequently, Röpke (2001) states that "we can define the environmental impact of a specific consumption good as the appropriation of inputs necessary to provide a unit of that good".

Along the same lines of thinking, the Göteborg European Council in June 2001 confirmed that *“the relationship between economic growth, consumption of natural resources and the generation of waste must change. Strong economic performance must go hand in hand with sustainable use of natural resources and levels of waste,…”* (European Council 2001, §31).

As far as it is possible to characterise (not: measure) environmental stresses by input analysis (see chapter 3.2.3), this approach provides a much simpler means of environmental monitoring than output-focused analysis. Not only is the number of substances entering the anthroposphere significantly lower than the number leaving it (some 200 inorganic materials as compared to several 100,000’s), also the entry gates are much fewer (in Germany about 20,000 as compared to several million exits to the environment, without air, but including water) (see (Spangenberg et al. 1999). Obviously a reduction of input would ceteris paribus reduce hazards and risks on the output side. If a reduction of input by, for example, a factor of 10 is achieved, environmental pressures on the output side are bound to decrease as long as the total toxicity for humans and the environment per kilogram of substance does not increase tenfold over the same time. Given the current knowledge about the detrimental effects of substances, however, it seems quite plausible that such an increase in substance-specific risks can be avoided (Anonymus 1999), although given the limited predictability of eco-system sensitivities, on a case-by-case basis still a serious risk remains. The total, however, should rather decrease significantly than increase. Thus the working hypothesis is that resource flows although not suitable for *measuring* the environmental pressures are a feasible tool to *characterise* them and in particular their dynamic. This hypothesis will be tested against the current key environmental problems in chapter 3.2.3, after the methodology of measuring resource consumption has been defined in chapter 3.2.2.

The trend of resource consumption increasingly becoming part of political and scientific discussions in evaluating and measuring environmental impacts is important for consumers as well. In shifting the focus of concern from the reduction of emissions to resource consumption, from industrial chimneys towards the sales point, this development is changing the role of households from being a victim of environment hazards to being co-producer. The growing attribution of environmental responsibility to households calls for their empowerment as actors, partly by equipping them with reliable information about the resource intensity of the goods and services on supply.

3.2.2 Measuring the Resource Inputs

Measuring energy consumption is a well established procedure, with annual energy consumption already an indicator in the CSD list (for the methodology sheets see UNDPCSD 1996, p. 166-167; UNDESA 1998).

Measurement of material flows has been developed more recently; at the macro level it is measured as total material requirement TMR (Adriaanse et al. 1997; Schmidt-Bleek et al. 1998; Spangenberg et al. 1999). However, intensity of material use is already one of the consumption-pattern-indicators in the CSD system (UNDPCSD 1996, p. 176-178), and TMR has been included in the list of indicators for measuring changes in consumption and production patterns (UNDSD 1998, p. 19-22).

Land use is so far a case less standardised with no quantitative measure internationally accepted. (UNDSD 1998, p. 26-28) proposed this indicator hoping for international agreement on the methodology and data generation, which has not materialised yet. In the absence of suitable quantitative measures, here a semi-quantitative (ordinal) one is proposed, based on a qualitative hierarchy of use intensities. For this paper it is sufficient to define the following four classes of land use, in decreasing environmental quality, which are related to a number of indicators for eco-system health in the revised CSD list of indicators (UNDSD 1999b):

- man-made, i.e. built environment, characterised by soil sealed off by settlement, transport and production infrastructure,
- anthropogenically managed eco-systems with high input levels, like intensive agriculture, dependent on the hands-on steering of the system dynamics by humans,
- naturally managed eco-systems with low anthropogenic inputs, like sustainable forestry or fishing, with the management heavily dependent on exploiting the inherent regulation mechanisms and humans restricted to setting some framework conditions,
- unmanaged eco-systems, like nature reserves and other protected or unused areas, with limited human influence, e.g. by forest dwellers or small-scale hunters and gatherers.

Given the need to reduce the current level of resource use significantly (a factor ten, one order of magnitude has been proposed for industrialised countries) (Schmidt-Bleek 1994; United Nations General Assembly 1997), it is plausible that all major options to decrease resource consumption will have to be used. In other words: a basic assumption for the further conclusions is that resource use reductions are undertaken consequently across the board, thus affecting all sectors and all environmental problems discussed in chapter 3.2.3. As soon as exemptions are deliberately introduced, the two-way correlation of resource flow reduction and environmental pressure relief would be broken.

3.2.3 Resource use and environmental problems: Causes and symptoms

Characterising environmental pressures and their trends by analysing the input side by its very character cannot result in a quantitative description of the various damages. However, it indicates which pressures have to be reduced and which corresponding changes in consumption clusters are needed in order to minimise (if not cure) the known environmental damages and as well minimise or prevent future ones (Hinterberger et al. 1996).

This kind of assessment is called *directionally secure* if with decreasing inputs the level of environmental damages will be decreasing with a high probability (Schmidt-Bleek 1994). The most serious of the current environmental problems can be addressed this way, except for those caused by relatively small flows of highly active substances like dioxins or pseudo-hormones (essentially an impact of the anthropogenically modified chemical environment on humans, not of humans on the environment). Politically speaking, such substances must be covered by health and safety regulations and banned from the sphere of the consumer, rendering the efforts to develop corresponding indicators superficial. This, however, is not intended to denote the need for proper information for the other actors like producers and public authorities.

Biodiversity

The classification of land use types is not only relevant to soil quality, but refers as well to the preservation of biodiversity. Since the latter, being defined as the combination of eco-system diversity, species diversity and genetic diversity cannot be measured directly (Spangenberg 1999), reducing the pressures must be the key approach. The most important ones generate from intensive agriculture and forestry on the one hand and from biotope destruction by infrastructure construction on the other, in particular for road transport. Thus in order to protect biodiversity, transformations to land use type one have to be avoided (even compensation measures in other places have little chance to offset the damage caused), and the shift from land use type two to three has to be encouraged, e.g. by financial means. The resilience of eco-systems will then safeguard biodiversity, with reduced fragmentation of natural systems the main additional recommendation beyond the reduction of resource consumption.

Climate Change

Global warming is caused by a variety of greenhouse gases of different origins. The most important are (for CFCs see ozone depletion):

CO_2 originates when organic materials are oxidised, mainly by burning fossil energy carriers. For a given energy mix, or in the case of slowly changing carbon intensity of the energy carriers incinerated, this output is directly related to the total energy consumption on the input side.

N_2O (nitrous oxide) originates not only from a few industrial processes, but mainly from agriculture, by over-fertilisation of cultivated areas. This is closely correlated with the second land use pattern on the input side; i.e. a shift to land use pattern three would significantly reduce the emissions.

CH_4 (methane) is emitted globally from rice paddies, cattle breeding and – in particular in industrialised countries – from waste disposals. Land use patterns cover the former aspect, while the latter corresponds to the total material requirement on the input side, all of which (apart from a small share going into the stocks) ends as waste.

Ozone depletion
Ozone depletion is mainly caused by CFC emissions. Due to their chemical stability, their effect will remain a hazard for a long time, even now that the global emissions have declined dramatically. Since by the Montreal Protocol to the Vienna Convention these substances have been regulated internationally, and in particular have been phased out in Europe, there is little left for households to do. Other substances (HCFC, Halons, Methylbromide, etc.) are in the process of being put under legal regulation and will vanish as well (EEA 1999b, appendix p. 7). Methylbromide in particular is mainly used in intensive agriculture and its phase-out would be accelerated by a shift from land use type two to type three.

Waste Generation
According to the EEA, “the EU is generating and transporting more solid waste. EU waste strategy goals have not been reached” (European Environment Agency EEA 1999, p. 11) and “new initiatives – requiring a comprehensive life cycle approach emphasising preventive measures and re-use – will be needed to stem predicted increases in most waste streams” (p. 19). A full life cycle analysis “not only requires [accounting] the materials and energy incorporated in the product or service itself, but also the materials and energy used in earlier stages of the production process (the ‘ecological rucksack’)” (p. 23).

On the input side, waste generation corresponds to material flows. More precisely, the total volume of waste is the material input into the economy minus flows stored in the stock plus flows from the stock (e.g. construction waste), i.e. material inputs of earlier accounting periods. Thus for the national level, the information demanded by the EEA is provided by the TMR methodology proposed.

Acidification

The level of acidification of lakes, rivers and soils is influenced by two main factors, the immission of acidifying substances through airbound transport and the buffering capacity of the affected eco-systems (particularly vulnerable eco-systems are found in Scandinavia). The three main substances causing acidification (i.e. cation release) are sulphur dioxide SO_2, nitrogen oxides NO_x and ammonium NH_4.

SO_2 originates mainly from the incineration of coal and crude oil. Since desulfurisation facilities ("scrubbers") are legally prescribed at power plants, the importance of this substance has diminished significantly and will decrease further with the EU-wide introduction of low sulphur petrol and diesel. For consumer behaviour, SO_2 is no longer an important concern.

NO_x subsumes NO and NO_2 generated in combustion processes of all kinds. Nitrogen oxides consist of the two main elements of the air and originate spontaneously with each high-temperature energy release (incineration, industrial processes, etc.). Due to emissions control legislation and the subsequent installation of denitrification facilities in industry and catalytic converters in cars, the growth of emissions has been slowed, without however breaking the trend of still growing emissions. Nitrogen oxide today is mainly generated by road transport and small-scale combustion. In both cases the combustion of energy carriers is the point of origin, permitting to correlate declining energy consumption with related decreases in NO_x emissions.

NH_3 originates from livestock production and manure management and like N_2O it can be attributed to intensive agriculture, land use class two on the input side.

Eutrophication

Eutrophication has mainly been caused by the immission of bio-accessible phosphorus and nitrogen into terrestrial and limnic eco-systems (i.e. the soil incl. ground water, and open waters like lakes and streams).

Phosphates were released mainly from washing agents, but those containing phosphates have been phased out in most parts of Europe. Emissions today mainly originate from agriculture, where phosphate is used as fertiliser in intensive agriculture (UBA 1997). Consequently, intensive agriculture, land use class two is the corresponding indicator on the input side.

Nitrate is emitted as a result of fertilisation (mineral as well as organic) in intensive agriculture. Again, land use provides a corresponding indicator linked to nitrate emissions from agriculture. Additional nitrogen stems from NO_x contained in precipitation and draining into the soil. As explained earlier, energy consumption provides an appropriate input indicator for the reduction of NO_x.

Summer smog

Summer smog is caused by high concentrations of ozone O_3 in the lower atmosphere as a result of photo-oxidisation, powered by solar radiation on sunny summer days. The main chemical components involved in this process are nitrogen oxides (see above), biogenic as well as anthropogenic VOCs, e.g. from gasoline, paints and dry-cleaning.

As described, gasoline consumption is accounted for by energy consumption on the input side, whereas for gas and dry-cleaning new standards are being developed and implemented, with little scope for consumer action, except for the choice of solvent free paints, which is also advisable for health reasons.

Soil Erosion

Erosion of soil is caused by the growing mechanisation and single plant cultivation of intensive agriculture, by clear cutting of forests, etc. A shift from intensive to organic farming, or from current practice to sustainable forestry would reduce erosion drastically. On the input side, erosion is thus characterised by the type of land use.

Conclusion

It has been demonstrated that by redirecting the growth trends in the consumption of *energy, material and land use* most environmental problems are affected in a directionally secure manner, thus permitting easier development of measures to curb pressures and of indicators to monitor progress. These indicators (see table 3.1) are also suitable to inform consumers on the respective environmental impact of different purchasing decisions, as will be shown in chapter 4. Supplying the consumer with this kind of simplified, directionally safe and transparent information could be instrumental in order to activate the power of demand-side environmentalism.

Table 3.1: Driving forces

Environmental problem	**Cause**	**Source**	**Key resource correlated**
Acidification	SO_2, NO_x	fossil fuels	energy
Biodiversity loss	habitat degradation	agriculture	land use
	fragmentation	settlements, roads	land use
Erosion	Use intensity	agriculture	land use
Eutrophication	P	agriculture	land use
	N	agriculture	land use
		airborne, fossil fuels	energy
Global warming	CO_2	fossil fuels	energy
	CH_4	ranching	land use
	N_2O	agriculture	land use
Ozone depletion	CFCs	cooling, solvents,…	N.A.
Waste generation	throughput	consumption volume	material flows

3.3 Consumption clusters — Where households can make a difference

In order to analyse the life-cycle-wide environmental impact of household consumption (not to be confused with the influence households have on environmental impacts), the national accounts based approach including public services consumption by households is the most appropriate one. As a next step, the total of household consumption can be disaggregated into the ten consumption clusters most frequently quoted in the literature. Applied to these clusters, the framework can serve to identify the most environmentally relevant ones by accounting for all resource uses activated by the consumption pattern, regardless of the relative influence of the actors involved. For the ten clusters chosen we find that together they represent more than 95 percent of private household resource consumption on the macro level (BUND/MISEREOR 1996). In alphabetical order they are:

- clothing
- education/training
- food
- health care
- housing (incl. construction)
- hygiene
- laundry and cleaning
- recreation
- social life
- transport

These clusters will be considered of prior environmental importance as fields of household decision-making if they are both environmentally relevant and accessible to significant influences by consumers' choices. The latter is here assessed by means of plausible reasoning, without a detailed sociological or political science analysis.

Three sectors can be identified which primarily consist of state and institutional consumption (Reisch, Scherhorn 1999), in which households as customers have limited influence on the frequency of services consumption, and hardly any on the (environmental) quality of service provision:

- health care: hospitals, rehabilitation institutions,…
- education/training: kindergarten, schools and universities,…
- social life: including the police, the military and other public services

Since the resource consumption per unit of service in the sectors is beyond the reach of consumer influence, they will be omitted from the further analysis of priorities for consumer action, regardless of their undisputed environmental significance.

When analysing the seven remaining clusters regarding their share in key resource consumption, it turns out that the total requirement of

- construction and housing,
- food and
- transport

adds up to nearly 70 percent of material extraction, energy consumption and land use. Each single cluster represents more than 15 percent of energy and material consumption (in this calculation, leisure mobility is subsumed in the transport category; if not so, leisure would emerge as the fourth sector of particular environmental relevance: Reich, Scherhorn 2000). The remaining four clusters

- hygiene,
- clothing,
- cleaning and
- recreation (without transport)

that can be influenced by households actually consume — if at all measured in detail — less than 5 percent of resource consumption each. Given the relatively small share in resource consumption, the limited although significant influence of households, e.g. on the resource intensity of clothing or cleaning agent production, and assuming that a straightforward reduction of consumption is indeed possible, but again only to a limited degree, a 10 percent reduction of total resource consumption in these four sectors together seems to be a conservatively estimated maximum potential. Although this is not a quantity to be ignored, these sectors are considered as fields of environmentally secondary action (maybe not so from a sociological point of view).

The following analysis and indicator development will therefore concentrate on the three environmentally dominant areas identified as *priority fields of action*: construction and housing, food and nutrition, transport and mobility (see table 3.2).

With this approach, hazardous impacts on humans' health *caused by the environment* will not be recorded. These include above all *chemicals with human-toxic effects*, i. e. cancerous, teratogenic, mutative, allergic and endocrinological substances but also eco-toxically doubtful, hardly biodegradable or bio-accumulating substances, as well as widespread and health relevant disturbances such as noise[2].

Table 3.2: Where households can make a difference

Consumption clusters	Influence of private Households	Environmentally relevance
Clothing	x	
Education/Training		x
Food	x	x
Health care		x
Construction/Housing	x	x
Hygiene	x	
Cleaning	x	
Recreation	x	
Social life		x
Transport	x	x

Whereas the importance of a specific good and service for sustainability is, in general, only minor, numerous goods and services have a symbolic function besides and above their utility function. Some of them indicate the membership in a certain social or lifestyle group or serve as a symbol of status for the compensatory consumer (Scherhorn 1991). The importance for environmental sustainability and the perceived symbolic value of the products or services consumed need not be matching at all. This lack of congruence, however, does not reduce the validity and importance of the communicative function. On this basis,

2 As long as goods and services contain such substances, their avoidance is an essential aspect of health conscious consumer behaviour. The protection of humans against toxic substances is, however, rather the task of national legislation in order to legally prohibit harmful goods and substances, than one of individual consumer choices. Thus toxicity concerns are a subject of sustainable production patterns rather than one of sustainable household consumption.

selected goods and services can be singled out that might serve as “icon indicators”, which due to their communications and social distinguishing function play an important role in sociological and psychological consumption analysis, however less in the environmental one.

4. Sustainable Household Consumption: The Indicators

In order to develop conclusive and communicative indicators for household use, the three priority fields of action (construction and housing, food and nutrition, mobility and transport) have to be analysed to identify the dominant factors driving resource consumption. The data presented below originate from Germany, but a similar situation can be assumed for most industrialised countries.

Based on the existing (partly quite poor) data, for each priority field a few consumption issues are identified that offer the most significant potential for reducing resource consumption. These will be explained in a subchapter titled "how households can make a difference". They will be characterised by indicators in the "indicators" subchapter, and the relative extent of influence of different actors including private households is discussed in the subchapter on "actors involved". The relative influence of the different actors in the field is estimated by common sense; the result is presented by a rough scheme with 0 = little influence, + = significant influence, and ++ = strong/dominating influence. As "sound institutional and social arrangements and eco-intelligent infrastructure can mould habits and steer behaviour without even touching the value question" (Reisch, Scherhorn 1999), providers of such infrastructure and social actors are relevant players to be taken into account in the influence schemes.

4.1 Construction and Housing

4.1.1 How households can make a difference

Energy consumption of housing accounts for 32 percent of the total demand, with heating representing 49 percent of the total households' energy consumption and thus considerably exceeding the 36 percent share of passenger transport (GRE 1997, p. 10). A reduction in the energy demand for heating would thus significantly contribute to sustainable household consumption. According to the German Society for Rational Energy Use 90 percent of the energy consumption needed for an average single family house (without gasoline) can be saved through the consistent use of energy saving equipment and measures. The resulting reduction of CO_2 twice exceeds the CO_2 emissions of a diesel passenger car running at 6 litres/100 km and travelling a distance of 25,000 km/a (GRE 1997, pp. 93 ff.).

According to material extraction calculations based on the official national economy statistics, construction and housing causes 29 percent of the total material consumption. This includes all raw materials and resources needed for the construction, extension and maintenance of apartments and houses including heating as well as materials that become necessary at the end of the life cycle in order to demolish the building. Annually in Germany 500 million tons of sand, gravel and stones are mined (data from 1990 for the former Federal Republic of Germany). 143 of the 338 million tons of waste in Germany (1993, data from UBA 1997) originate from the construction industry (including road construction). To this a significant share of the 68 million tons overburden from mining per year has to be added, plus some of the production (total: 78 million tons) and the domestic waste (total: 44 million tons).

The construction sector is the main contributor to the increasing sealing of soil, with 85 percent of the approved building projects in 1994 dedicated to housing. Under a business-as-usual scenario, the total settlement area is estimated to increase by 370 km^2 by 2010 (Deutscher Bundestag 1998). 84 percent of this area will be used for single family houses. Thus the housing sector offers significant opportunities for savings regarding land use, material flows and energy consumption.

4.1.2 Indicators

Indicator 1: Heating energy consumption (kWh / m^2 a)

This indicator is already established in expert discussions and will be an essential part of an “energy passport” for real estate that will be introduced in the year 2001 (GRE 1997, p. 96). Quality benchmarks already exist for different types of buildings.

In practice the indicator can be used by architects and investors to check their investments and plans, and by households as a selection criterion for the new flat or house when a household has to move.

During the phase of use, however, it does not indicate specific action to be taken but can be a means to monitor whether thermal insulation work undertaken by the tenant has been successful.

Indicator 2: Settlement area (m^2 / cap)

Settlement area is one of the main contributors to the land use category 1, together with transport and production infrastructure. Measuring the development of land use for settlement purposes will therefore serve to indicate the sustainability of our settlement patterns.

The indicator measures the long-term trends in housing; although only to a limited degree attributable to day-to-day consumption decisions, it is driven by consumer choices as regards the flat or house they rent, buy or build. It thus characterises one important aspect of our overall lifestyles and consumption patterns.

Indicator 3: Relation of private investment in existing houses to the erection of new buildings (dimensionless)
Modernising existing flats and houses to the standard of modern housing equivalent to that of new constructions reduces material flows and land use per unit of functionally identical output significantly (Deutscher Bundestag 1998). The indicator monitors the trend in private household expenditure relevant regarding this alternative.

Currently the Federal Republic subsidises new private house constructions heavily, but still the future owner has to contribute significant matching funds. Thus the indicator also reflects the flow of subsidies, and in case their priority should be changed from erecting new buildings to maintaining existing ones as suggested by the Federal Parliament's Commission (Deutscher Bundestag 1998), it monitors the degree to which households react to such changes in financial incentives.

Indicator 4: Resource intensity (kg / m^2 a)
The total material flows can be diminished considerably through reduced resource intensity in the sector of housing construction by using recycled materials and those which can be easily rebuilt or demolished, or by refusing to build cellars. Recent technological achievements (i.e. ultrasonic recycling of concrete by decomposing it into the re-usable single materials sand, gravel and cement) will hopefully lead to more reduction potentials in future.

Indicator 5: Living space (m^2 / cap)
A valid calculation of individual resource consumption cannot be achieved by means of heating energy consumption and resource intensity measured in kg/m^2. A single person will presumably consume less energy than a 4-person household in an equally sized flat. The living space per person provides additional information necessary in order to avoid misinterpretations.

Empirically, energy and material consumption is correlated to the living space area per capita (Deutscher Bundestag 1998). Currently, the living space per capita tends to increase with the age of a person, and in each age group grows over time. This is a reason for environmental concern regarding future resource consumption, in particular when taking demographic change into account.

4.1.3 Actors involved

Housing is characterised by a high diversity of actor-specific, but frequently overlapping potentials for influencing energy consumption and material flows as well as land use. Different actors are influencing planning and construction, investments (construction or modernisation) and everyday use patterns. Private households are important actors (++) for a number of reasons:

- Nearly all housing expenditure (monetary and physical) can be attributed to private households, either as users or as property owners. In Germany, 38.7 percent of all flats are freehold property; in houses consisting of one or two flats, the share of freehold property is 71 percent. In these cases, the households are owners as well as residents, with the influence increased accordingly.
- Private households play an important role with respect to decisions on sustainable housing modernisation. They influence to a considerable extent the amount of material, energy and water needed for construction and residence, in particular by deciding about the apartment size (even if socio-economic constraints are taken into account).
- As owners, they determine heating energy consumption by deciding about thermal insulation, the choice of more or less efficient heating systems and the like.
- The patterns of airing, chosen room temperature and the time heating is operated daily influence heating energy consumption significantly, at a given level of living comfort (up to a factor of 2 due to different consumption behaviour). This way, residents can determine the amount of heating energy consumed by their consumption behaviour (and through minor renovations, e.g. for the sealing of joints).

A similar pattern of influence like for private owners (+) is attributable *to public or corporate owners* (+) of rentable flats. One important difference, however, is the investor-user-dilemma that occurs if the house owners' investments, e.g. in energy saving, benefit the resident and his/her energy bill, but not the investor. In these cases, *energy service providers* can help (+) through contracting arrangements, i.e. by paying for and managing the investment and in return repaying its benefits by charging the consumer a stable price, although the costs are decreasing. Whereas the resulting surplus makes up for the profit of the contractor, the owner has a modernised (and thus value increased) property, and the households benefit from stable energy payments below market prices.

Local authorities (+) significantly influence land use by dedicating specific areas for housing purposes and defining standards associated with building permits. *Regional planners and architects* influence settlement structures (living area +) as well as the standards of construction (resource intensity +). They do so by providing low energy consumption and resource efficient housing, and they could help offering flats of flexible size which permit a regular adaptation of living area to the changing size of a family.

Loans banks (+) define funding criteria and thus influence the standard of housing – a capacity that could easily be extended to energy and material efficiency standards.

Political regulation frameworks (+) and *subsidies* (+) strongly influence if not determine the households' decisions whether to invest in the construction of new houses or whether to renovate old ones. Taxation of living area, material input and energy taxation, energy consumption standards play a significant role (+), as do criteria for granting subsidies. In Germany, public support for new developments was 27.1 billion DM in 1996, compared to 8.4 billion for upgrading existing houses.

Table 4.1 illustrates the diversity of actors involved as well as their different but overlapping spheres of influence, according to the reasoning above. These results are based on common sense; for a validation of these estimates or even for their quantification detailed social science studies would be required.

Table 4.1: Indicators for Construction and Housing

	Private households						
	Residents	Property owners	Public owners	Corporate owners	Local authorities	Planners	Service providers
Heating energy consumption	+	+	o	+	+	+	+
Resource intensity	o	+	o	+	+	+	+
Living space	++	+	+	+	+	+	o
Private investment in existing houses / erection of new	o	++	+	o	+	o	o
Settlement area	o	+	++	+	++	o	+

4.2 Food

4.2.1 How households can make a difference

In Germany the food chain's share in energy and material consumption runs at 20 percent. Agricultural area, 97.9 percent of which was intensively farmed in 1999 (SÖL 1999), covers 56 percent of Germany's total land area. It furthermore has a considerable water pollutant and eutrophication impact as 38 percent of the total nitrogen input and nearly 40 percent of the phosphorus input originate from agriculture (Burdick 1998). Detrimental impacts on the soil are caused by erosion and pesticides.

The output of greenhouse gases, measured as CO_2 equivalents, is a severe issue in the field of food and nutrition. In order to feed Germany's 80 million citizens, 260 million tons of CO_2 equivalents are emitted per year, i.e. 3.2 tons per inhabitant (Deutscher Bundestag 1994). Table 4.2 provides the data disaggregated by sectors involved.

Table 4.2: Greenhouse gas emissions from the food chain

Sector	Mio. t CO_2 equivalent	percentage
farming, crops	20	7,7
farming, livestock	115	44,2
food industry	15	5,7
trade, other distribution	35	13,5
consumer activities	75	28,9
total	260	100

According to the methodology of this study, however, the calculation has to be adjusted by eliminating transport and heating to avoid double accounting (transport for shopping purposes, heating of kitchen and dining room). With this adjustment, the food sector's total CO_2 equivalents emission runs at 227 million tons. On the other hand, the consumer activities' share of 42 million or 18.5 percent given in table 2.2 is misguiding, since households could influence environmental resource consumption in the production phase significantly (+) by selecting particular, e.g. organic, food or by adopting a less meat intensive diet.

4.2.2 Indicators

Indicator 6: Meat consumption (kg / cap a)
From a health care point of view a reduction in meat consumption has a number of positive effects, but these will not be dealt with in detail in this paper. Here we refer to the environmental significance of meat production:

- The emissions of the livestock production sector of 115 million tons CO_2 equivalents are six times higher than those of the crops sector (20 million tons CO_2 equivalents; see table 2.2).
- To produce meat, large areas of land are needed. In Germany 60 percent of the farmland is used for the cultivation of feedstock, and additional feed is imported from the EU and from overseas.
- Ammonia emissions caused by pork breeding contribute significantly to regional acidification and eutrophication.
- Dung water contributes to ground water pollution (in some areas, the majority of natural wells are no longer suitable for drinking water purposes due to high nitrate concentrations), and it contributes to the nitrogen input to fragile eco-systems via water and air.

Indicator 7: Organic products (% market share of food products)
Organic agriculture leads to a considerable reduction in pollution as no pesticides and less fertilisers are used. Thus the pesticide and nitrate leakage into the ground water are diminished and the biodiversity of accompanying plant and neighbouring eco-systems is significantly higher than on intensively farmed land. Adequate animal breeding is not only an ethical issue, it lowers the amount of pollutant substances released as well.

The energy consumption of organic farming is only one third of conventional farming as no synthetic fertilisers are used and no additional feedstock is imported (Haas 1994). Furthermore, the volume of erosion caused by organic agriculture is significantly smaller than in intensive farming.

Indicator 8: Food transportation
The distribution of food is after livestock production and consumption activities the third biggest factor contributing to the resource consumption of the food sector, with increasing tendency. The growing average transport distances are furthermore increasing the demand for transport infrastructure, in particular through increasing road transport (here only transport to the retailer is accounted for; the transport from the shop to the home is covered by the mobility indicators).

The preferable indicator would thus be based on product specific transport analysis, including domestic and foreign intermediate products and services, packaging, etc. Given the existing restrictions in data availability, the total domestic transport efforts for food and feed is taken as an approximation, since these data are available in the German national statistics. For other countries, similar proxy indicators may be suitable.

4.2.3 Actors involved

The influence of *households* on the environmental impacts of food production and consumption goes far beyond the patterns of cooking and cooling. By expressing their preferences at the shopping counter, households have a significant influence on the kind of food produced, the mode of production and thus the environmental impacts. This make the role of households particularly important, although other actors play significant roles as well.

Their influence is limited, however, as regards the transport intensity of the food purchased, due to the lack of information (labelling) as well due to the absence of substitutes.

For this aspect, *traders* and *retail companies* are more influential, but the supply structures (e.g. limitations in regional organic food provision) are equally important. They can be improved by the *farming sector*, but this is at least partly dependent on the market conditions and cost structures determined by *politics*, in this case particularly by the European Union's Common Agricultural Policy CAP.

Finally, the food industry and restaurants are additional actors on the supply side, with the latter having similar choices to the private households regarding the menus they offer, but restricted by market demand. All these actors are included in table 4.3 below.

Table 4.3: Indicators Nutrition

	Private households	Retailers	Farmers	Food industry	Politics	Restaurants & Caterers
Meat consumption	++	+	+	+	+	+
Organic products	++	+	++	+	+	++
Food transportation	+	+	o	+	+	+

4.3 Transport

4.3.1 How households can make a difference

The growth of transport volumes and distances, as opposed to energy and material consumption, for which at least a partial decoupling from GDP had been achieved in the 70s and 80s, is still closely linked to economic development. Furthermore, the trend in modal split for goods as well as for people goes towards more unsustainable modes like road or air transport.

While the transport volumes are reaching the limits of capacity of the road system, transport infrastructure has become a major driving force in land use and eco-system fragmentation. Although not yet the sector with the highest greenhouse gas emissions (except for some countries like New Zealand), transport is the sector with the highest annual growth rates. 50 percent of the global mineral oil consumption is for gasoline, making up for one fourth of the total greenhouse effect. In Germany this rate is 30 percent (Petersen, Schallaböck 1995, p. 112). 32 percent of the OECD member countries' primary energy consumption occurs in the transport sector with the United States at 37.4 percent and the European OECD states at 27.2 percent (OECD 1998, p. 21). Not included in these numbers are the CO_2 amounts (including CO_2 equivalents of other greenhouse gases) caused by the production and maintenance of vehicles and infrastructure, which are part of the "ecological rucksack" of transport. Citizens consider transport as by far the most severe quality of life problem on the local level. Statistics on transport activities (number of new car licences, km travelled for passenger and goods transport, energy consumption in the transport sector, etc.) show that up to now all concepts for transport reduction have failed (Akademie 1997, p. 197).

According to the German Federal Statistical Office (Statistisches Bundesamt 1997), private households contribute 96.4 million tons CO_2 (directly) and 68.3 million tons CO_2 (indirectly) to the emissions from transport. With respect to this, the goods transport sector plays only a minor role compared with that of passenger transport, but the rate of certain substances released here should not be underestimated. The share of transport and of road transport emissions in particular is given in table 4.4:

Table 4.4: Share of total emissions caused by transport

Emissions	**Share of transport**	**thereof share of road transport**
CO_2	20%	80%
NO_2	60%	50%
carbon hydrogen	33%	30%

Source: (Akademie 1997)

About 83 percent of emissions can be attributed to passenger transport and 17 percent to freight. They affect a variety of environmental domains:

- *Water pollution:* eutrophication of water by input of nitrogen oxide; ground water contamination by leakage of oil and gasoline.
- *Soil degradation:* vehicle emissions contribute to acid rain partly caused by nitrogen oxide and to eutrophication of soil and ground water by nitrogen input from the atmosphere.
- *Land use:* 4.6 percent of the total area of the Federal Republic of Germany is occupied by transport infrastructure (Statistisches Bundesamt 1997), more area than for construction. The total land claimed for transport purposes is much more than only the road area, including petrol stations, repair shops and private parking areas. The indirect land occupation by noise corridors, etc., is not included in this calculation as well.
- *Other hazardous impacts include* the emission of substances like platinum, fibres, aldehyde and others; noise caused by vehicles and aeroplanes; odours; degradation of living spaces; resource and energy consumption by emissions resulting from production and disposal of vehicles and infrastructure (Petersen, Schallaböck 1995, p. 69).

4.3.2 Indicators

Indicator 9: Shopping and recreation transport distances (km / cap a)

Transport activities for shopping and recreation purposes are not only strongly dominated by passenger car use, they also account for more than half of the kilometres covered per person (see table 4.5). Even if these transport activities are not “voluntary”, private households have at their disposal significant potential for choosing more sustainable means of transport.

Table 4.5: Passenger car transport: distances and person-kilometres per transport purpose

Transport purpose	distance (%)	person-kilometres (%)
shopping	27	11
recreation	40	40
occupational	0.2	9

Source: (Petersen, Schallaböck 1995), p. 69

Changing framework conditions, like increasing individualisation of lifestyles, the growth of single person households, suburban shopping malls and transport intensive leisure time activities all contribute to growing transport distances covered by private households, while commuting is decreasing in its relative importance. Settlement structures induce transport activities by increasing or diminishing the distances. So do the means of transport available, while the mobility rate (the number of trips) has remained quite constant in Germany over the last fifty years (Petersen, Schallaböck 1995, pp. 9 ff.).

The category of “leisure mobility”, however, is problematic as far as it is a residual entity in transport statistics for mobility not induced by paid labour. It includes transport from reproduction and voluntary work (Spitzner, Aumann 1995). This kind of transport, however, is characterised by quite low levels of elasticity regarding the mode of transport (Spitzner, Beik 1996).

The indicator proposed focuses on the distance covered, since societal trends like shorter job duration, longer educational or unemployment phases or the trend towards higher female employment participation resulting in increasing numbers of working couples with two distant work places, lower the private households’ possibilities to avoid transport. However, as regards occupational and educational transport activities, private households are free to select the means of transport they use, at least as long as sufficiently convenient choices are available.

Indicator 10: Modes of transport for vocational purposes (share of cars, rail and other public transport, non-motorised transport)
In recent years the functional separation into inner-city working and outer-city living areas has led to an ever increasing number of commuters. Their mode of transport has a significant influence on the resource consumption for transport. For commuting, this is to a significant degree open to consumer decisions, whereas the frequency and distance of trips is overwhelmingly beyond their influence. Vocational purpose transport is dominated by cars, with still increasing shares (in Germany except for educational purposes).

As the frequency of transport activities for occupational, educational/training and business purposes by and large cannot be influenced by private households, the indicator refers to the transport activities for shopping and recreation purposes. Indicators like “commuter rate” and “commuting distances” are regarded good indicators for planning purposes, but are less suitable for indicating consumer behaviour.

Indicator 11: Modes of transport for shopping and recreation purposes (share of cars, rail and other public transport, non-motorised transport)
Factors which decisively influence the selection of transport means are: subjective needs, individual preferences and values. Sustainable consumption behaviour at the present state of the art can be predominantly expected in those consumption clusters that require the least personal efforts (low-cost hypothesis). However, some studies indicate that individuals regard the transport sector as a high-cost one.

As pointed out already, the environmental impact of transport is determined by the frequency of trips, the distance per trip and the mode of transport. Since the transport distance for recreation and shopping is already covered by another indicator, this one monitors the modes of transport. Thus the environmental sustainability of consumption is strongly influenced by the modes of transport chosen.

Indicator 12: Number of passenger cars per 1000 inhabitants
Empirical studies show that even proven environmental awareness does not significantly influence the mobility behaviour of car owners. Once a car is available, it is used as frequently as in other car-owner households.

On the other hand, environmental concerns are instrumental in the decision whether to buy a car not, opting, for example, for a combination of car sharing, rental cars and public transport.

Indicator 13: Holiday flights (km / cap a)
Despite the still relatively small environmental resource consumption of aviation, it needs to be monitored due to the current trends that more people use air transport to fly more frequent flights to ever more distant destinations.

This corresponds to a steep increase in energy and resource consumption which is not sustainable in the long run.

Indicator 14: Average energy consumption of new cars (l gasoline / 100 km)
From the users' point of view the use of the private passenger car is actually the quickest, most comfortable and economically attractive means of transport, especially as the costs for the railway network are included in the ticket price whereas the costs for the road network are independent of distance travelled. The car will remain a predominant means of transportation unless there is a change of circumstances.

24 percent of the energy consumption by household is caused by transport, 60 percent of this by gasoline consumption (Statistisches Bundesamt 1999). Besides the transport distances, frequencies and the mode of transport, the efficiency of the cars used has a major impact on energy consumption. This efficiency is determined by two factors: the technical efficiency of the car itself, and the style of driving. This indicator focuses on the former, which can be influenced mainly in the phase of buying a new car

4.3.3 Actors involved

Private households are a key actor in determining transport efforts. 41.4 million cars are registered in Germany (Statistisches Bundesamt 1997), 58 percent of all households own a private car; an additional 23 percent own two or more. 56 percent of all West German and 66 percent of all East German citizens have not used railways in the last year (BMU 1998, p. 54). Aviation shows the highest annual increases (7.5 percent) of all transport activities, with holiday flights playing an important role. Regardless of external constraints, households dominate the decision on the mode of transport, but the availability of suitable and convenient alternatives is important as well. *Local authorities* and *service providers* can do a lot in this respect, by offering or reducing the supply of infrastructures for mobility (public transport, parking areas, etc.) and by increasing or reducing the need for mobility through planning and more or less centralised service availability. *Employers* influence commuting behaviour by financial and administrative incentives.

Travel agencies and *tourism companies* influence holiday transport, car sharing providers do so for the rest of the year. *Political decisions* can increase or decrease the cost of mobility, thus setting incentives for more or less resource consumption for transport purposes. Thus the legislative and administrative authorities are important actors for the development and implementation of a new policy in this sector. We differentiate measures that

1. make alternative means of transportation more attractive (pull factors), and
2. make passenger car transport more expensive or otherwise less convenient in order to reduce it (push factors).

Finally the efficiency of means of transport is determined by *industry* as well as by their customers. Table 4.6 illustrates the overlapping spheres of influence.

Table 7: Transport Indicators

	Private households	Leisure industry	Local authorities	Politics	Industry	Service providers	Employers
Shopping/recreation transport distance	+	+	+	+	o	+	o
Transport for vocational purpose	+	o	+	+	o	+	+
Transport for shopping and recreation purposes	++	+	+	+	o	+	o
Number of passenger cars	+	o	+	+	+	+	o
Average energy consumption	+	o	o	+	+	+	o
Holiday flights	++	+	o	+	o	o	o

5. Sustainable Consumption Indicators for the IWPCCPP

This chapter illuminates how the methodology developed in this paper could be applied to fill the gaps still existing in UNDESA's international work programme for sustainability indicators on changing consumption and production patterns as introduced in chapter 2.

5.1 Indicators as an Information Tool for Sustainability Policies

One element of unsustainable consumption in the affluent consumer societies is the consumption by private households (Lorek et al. 1999; Spangenberg, Lorek 2001). Similarly, the private consumption of affluent households in poor societies can be environmentally and socially unsustainable. However, except for the work on the Environmental Kuznets Curve hypothesis (see e.g. Ecological Economics 1998), there are only few empirical studies on the environmental impact of wealth. One example, based on the methodology given in this paper, comes to the conclusion that today wealth is not used for more sophisticated, high quality and high efficiency consumption, but is in many cases more of the same or more of particularly resource intensive goods, services and activities (Lorek, Spangenberg 2001). Our current pattern of wealth is environmentally unsustainable, and if the pursuit of happiness will continue to translate into a strive for permanent economic growth for the majority of humankind, the degradation of the global environment will continue. However, whereas growth as such does not lead to environmental relief (Spangenberg 2001), at least for the medium term economic growth and environmental protection can be reconciled if a proper policy framework is developed and implemented (Hans-Böckler-Stiftung 2001), including a transition of wealthy consumption towards more quality of life from less resources (Spangenberg, Lorek 2001). For this behalf, besides the appropriate preferences and in order to make them effectively transparent (i.e. no information overflow) and reliable (i.e. still directionally secure), information is needed as to which way of satisfying demands will do so with minimal environmental impacts.

Unfortunately, so far only limited knowledge has been obtained on the *real contribution* of households to the total environmental burden of the respective countries and how they can influence it significantly. The approach presented in this paper (chapter 3) aims at overcoming that obstacle to sustainable development by identifying the environmental influence of households. The indicators suggested help to identify the possible contributions of households to the development of environmentally sound consumption. In this respect, the system of indicators developed in this paper and the set suggested by UNDESA share a common purpose. Consequently it makes sense to look for commonalities and possible synergies by comparing the two sets of indicators.

5.2 Links to the CCPP Work Programme

When UNDESA published their set of sustainable consumption indicators, the list was based on an extensive expert consultation process. The indicators were well founded, although not explicitly linked to any specific analytical approach or methodology. However, when comparing the approaches and results, it is obvious that the environmental space based approach introduced in this paper (Spangenberg, Femia et al. 1999; Spangenberg, Hinterberger et al. 1999) strongly supports and partly complements the scientific basis of the indicator set on Changing Consumption and Production Patterns as suggested by UNDESA (UNDESA 1998). With these similarities it is no surprise that most of the UN indicators are covered as well by the indicator system developed in this study in a more systematic manner. The key resources identified as core of the consumption patterns show striking similarities (see table 5.1). For materials even the indicators are identical, for energy they are at least closely related, while for land use the ordinal indicator presented in this paper is slightly more sophisticated than the CCPP proposal.

Table 5.1: The CCPP Core Set of Indicators and the corresponding ESHC[a] indicators

CCPP Key Resources	ESHC[a] Key Resources
Energy	Energy
p.a. per capita, Intensity, Price, % Renewable	p.a.
Materials	Materials
TMR	TMR
Water	(included in material flows, since not a separate issue in Germany)
Intensity	*(no indicator)*
Land	Land
Land use	Land use

[a] **E**nvironmental Space based Household Consumption

Whereas for energy, materials and land the environmental indicators are quite similar, the only substantial difference is the fact that the category of water is not explicitly mentioned in the environmental space based set of indicators. The difference is easily explained by the fact that water is one key category in the material flow accounts, although usually not singled out as a separate indicator (Spangenberg 1999). This is due to the fact that the indicators developed on behalf of the German Federal Environmental Agency are to be applied to Germany, a country where there is no overall water shortage and which experiences local supply problems only from time to time.

Table 5.2: The CCPP Core Set and the corresponding ESHC[a] Indicators

CCPP Consumption Clusters	ESHC[a] Consumption Clusters
Mobility	Mobility
distance, no. of vehicles	distance, no. of vehicles per capita, car use, plane
Building and Housekeeping	Building and Housekeeping
energy use, water use, pers./flat	energy use, resource use, m^2 per capita area, investment in existing stock
Food	Food
% more sustainably produced	meat per capita, % organic, foodmiles
Recreation	*(Recreation mobility, addressed under mobility category)*
spending (time & money) as % of disposable income	(distance per activity, holiday miles)
Consumer Goods and Services	*(Symbolic goods)*
retail sales of selected goods per capita market share of sustainably produced goods and services	*(either "icon indicators" signalling lifestyles or of specific environmental relevance)*

[a] **E**nvironmental Space based Household Consumption

For the application of the environmental space methodology to other countries – in particular in arid areas – it is possible to make the category of water explicit without compromising on the other aspects (Spangenberg 2000). Comparing the consumption clusters analysed by the CCPP programme and in this paper, again striking similarities can be found. Whereas mobility, building and housekeeping, and food are common categories, and the indicators even overlap significantly, for the other consumption clusters identified by UNDESA (recreation, consumer goods and services) the situation is different (see table 5.2).

- For food, UNDESA has not yet developed a specific proposal for indicators (see chapter 2), and the three ESHC (Environmental Space based Household Consumption) indicators suggested at least in combination could provide a good starting point for developing sustainable food indicators.
- As opposed to the UNDESA proposal, which identifies a specific consumption cluster for recreation, this study follows a different line of analysis. Whereas the total environmental impact from recreation is no doubt significant and needs to be taken into account, the cluster looks less impressive once those factors are eliminated from the assessment that are already covered by other indicators, in order to avoid double accounting. This is particularly true for recreation mobility (included in the mobility category), but refers as well to hotels, holiday apartments, and other infrastructure covered by building and housekeeping, and restaurants included in the food sector. The remaining recreation activities do not suggest themselves as a relevant category or consumption cluster of its own.
- For consumer goods and services, the selection criteria provided by the CCPP core set is that they have to be "selected" and "more sustainably produced" (UNDESA 1998). Indicators suggested are "retail sales of selected goods per capita" and "market share sustainably produced goods and services".

However, what does *"sustainably produced"* or *"selected"* goods and services mean in the DESA definition of indicators? So far, no operational definition of these indicators has been found, since for the definition of *"selected goods"* and *"sustainably produced goods and services"* some groundbreaking work is needed to provide a solid basis for the definition of indicators. A solution to this problem might be found in the consumption indicator methodology presented in chapter 3 of this paper.

5.3 A Procedural Proposal

In order to answer the question what sustainably produced selected goods and services might be, it first has to be clarified what the criteria are on which an assessment for the sustainability of products and services could be based. With a methodology as described above, environmentally relevant consumption clusters could be identified. Relevant here refers to the key resources the UNDESA has chosen.

Once these clusters are identified, the task of finding the selected products can be redefined to find those products which can best indicate the transformation of relevant consumption clusters towards a more sustainable pattern, e.g. two functionally equivalent consumer items with extremely different resource intensities. Quite obviously, any such selection would have to be due to regular assessment and updating, since it is indicating consumer preferences, i.e. a moving target.

To identify suitable products, however, the resource intensity analysis has to be brought down to the micro level by applying methodologies like embodied energy calculation (King 1994) and the material input per service unit MIPS (Schmidt-Bleek 1998) to check specific products for their life-cycle-wide resource consumption. The accumulated knowledge could be used to identify those sustainably produced environmentally relevant selected goods and services that could serve as "icon indicators" in the CCPP programme.

6. References

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Glossary of Abbreviations

BMU	Bundesministerium für Umwelt (German Ministry of Environment)
CAP	Common Agricultural Policies of the European Union
CCPP	Changing Consumption and Production Pattern
CSD	Commission on Sustainable Development
EEA	European Environmental Agency
EU	European Union
GDP	Gross Domestic Product
GWP	Greenhouse Warming Potential
IWPCCPP	International Work Programme on Changing Consumption and Production Patterns of UN-DESA
MIPS	Material Input per Service Unit
NGO	Non-Governmental Organisations
ODP	Ozone Depletion Potential
OECD	Organisation on Economic Co-operation and Development
SNA	System of National Accounts
StBA	Statistisches Bundesamt
TMR	Total Material Requirement
UBA	Umweltbundesamt (German Environmental Agency)
UN	United Nations
UN DESA	United Nations Division on Economic and Social Affairs
UN DSD	United Nation Division on Sustainable Development
UNCED	United Nation Conference on Environment and Development
UNCTAT	United Nation Conference on Tariffs and Trade
WPISD	Working Program on Indicators for Sustainable Development

Chemical formulas

CO_2	Carbon dioxide from any kind of combustion is the main greenhouse gas, causing more than 50 percent of climate change
CFCs	Chlorofluorcarbons, used as solvents and spray gas, extremely long-lasting, destroy the ozone layer and have a significant GWP
N_2O	Dinitorogenoxide, an important greenhouse gas
CH_4	Methane from oxygen-free destruction of organic matter in rice paddies and waste dumps or from the fossil fuel industry, as a greenhouse gas about 20 times as effective as CO_2
HCFC	Hydrogenated CFCs, substitute for CFCs, similar chemical characteristics, but more easily degradable and thus less long-living
SO_2	Sulphur dioxide, results from combustion of fossil fuels without scrubbers, causes acidification
NO_x	Nitrogen oxides (NO, NO_2) result from combustion of fossil fuels without scrubbers, cause acidification and contribute to tropospheric ozone generation
NH_4	Ammonium, from manure of intensive agriculture, causes acidification
NO	Nitrogen oxide, from all combustion processes with insufficient oxygen supply
NO_2	Nitrogen dioxide, from fossil fuel combustion with air containing molecular nitrogen N_2
O_3	Oxygen, essential for life, in circular flow with CO_2 through plants and animals
VOC	Volatile organic compounds in gasoline, solvents, etc., contribute to summer smog and ozone